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PROCESS - PLATING - TIN ON ALUMINUM AND ALUMINUM ALLOY - CHEMICAL AND PHYSICAL PROPERTIES - INVESTIGATION OF

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GROUP: CHEMISTRY SECTION
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FTDM 1925, T.R.F 6681

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PROCESS - PLATING - TIN ON ALUMINUM AND ALUMINUM ALLOYS - CHEMICAL AND PHYSICAL PROPERTIES - INVESTIGATION OF

PURPOSE:

At the present time there is an urgent need for evaluation of a metallic coating for aluminum to be used in contact with HK-31A magnesium-thorium alloy. Electrodeposited tin has been recommended as an effective coating for reducing galvanic corrosion between these materials. There are two pretreatment and three plating methods which require investigation to determine the sequence most suitable for the present need. Data on the physical and chemical properties of electrodeposited tin on aluminum alloys are also needed to establish requirements for Convair Process Specification FPS-OC29 which is being prepared.

SUMMARY:

These investigations involved (1) the preparation of tin electroplated 2024-T6 and 7075-T6 aluminum alloy specimens and (2) the evaluation of the physical and corrosion resistant properties of the plated specimens.

A. Plating of Specimens: Six plating procedures were evaluated, involving two pretreatment methods: (1) "Alumon" Zincate immersion coatings and (2) Oxalic Acid anodize. These pretreatments were followed by tin electroplating from (1) Stannous Fluoborate, (2) Sodium Stannate and (3) Stannous Sulfate plating baths.

Procedures which employed the use of the "Alumon" Zincate immersion pretreatment (Nos. 1, 2 and 3 of Table II) produced attractive, uniform tin platings on both 2024-T6 and 7075-T6 aluminum alloys. The Oxalic Acid anodize pretreatment failed to produce surfaces receptive to electrodeposition. As a result, procedure nos. 4, 5, and 6, Table II, were found unsatisfactory and were not evaluated by physical and corrosion tests.

B. Evaluation of Tin Plated Specimens: The plated specimens of each aluminum alloy were visually inspected and were then subjected to tape stripping, bend, and thermal cycling adhesion tests. All specimens which were prepared by procedure nos. 1, 2 and 3 exhibited excellent physical properties.

Specimens of each aluminum alloy and plating procedure were given 200 hours exposure to salt spray environment. Platings produced by procedure nos. 1 and 3 failed to offer sufficient corrosion protection to either aluminum alloy, whereas the platings produced by procedure no. 2 ("Alumon" Zincate pretreatment plus Sodium Stannate tin bath) offerred an acceptable degree of corrosion resistance to both alloys.

Tin plated 2024-T6 and 7075-T6 aluminum alloy specimens were coupled to HK-31 magnesium-thorium alloy pads in accordance with the procedure given in Table IV, and the couples were subjected to 100-hours immersion in a three-phase JP-4 - 3% salt water system. Specimens were examined for possible corrosion after 50 and 100-hour exposure periods. No indication of corrosion was evident. All three plating procedures produced plates which were effective in eliminating galvanic corrosion under these conditions.

PROCESS - PLATING - TIN ON ALUMINUM AND ALUMINUM ALLOYS - CHEMICAL AND PHYSICAL PROPERTIES - INVESTIGATION OF

OBJECT:

To investigate the chemical and physical properties of tin electrodeposited on 2024-T6 and 7075-T6 aluminum alloys by various pretreatment and plating procedures.

TEST SPECIMENS, MATERIALS AND EQUIPMENT:

Specimens, materials and equipment employed during these test procedures are listed in Table I. Specimens were of 2024-T6 and 7075-T6 aluminum and HK-31A magnesium-thorium alloys. All equipment used in the test was permanent equipment of the Engineering Chemistry Laboratory.

PROCEDURE:

A. Plating and Preparation of Test Specimens: Tin plating thicknesses of 0.0005" to 0.00075" were electrodeposited on 2024-T6 and 7075-T6 aluminum alloy specimens by the procedures outlined in Table II. Combinations of two pretreatment and three plating methods were evaluated. The plating bath compositions and operating conditions are given in Table III. Tin plated aluminum coupons were coupled to magnesium-thorium pads in accordance with the procedure outlined in Table IV.

B. Physical Testing of Tin Platings: Specimens were evaluated for adhesion of the tin platings by tape stripping, bend and thermal cycling tests. Detailed procedures for performing these tests are given in Table V.

C. Corrosion Testing of Tin Plated Specimens: 2024-T6 and 7075-T6 aluminum alloy coupons which were plated by procedures 1, 2, and 3, Table II, were given a 200-hour exposure to salt spray environment in accordance with Federal Test Method Standard 151, Method 811. The tin plated aluminum-magnesium-thorium couple specimens were subjected to 100-hours immersion in a three-phase JP-4 - 3% salt water system as outlined in Table V.

RESULTS:

A. Electroplating of Aluminum Specimens: Attractive tin plates were produced on 2024-T6 and 7075-T6 aluminum alloys by the procedures incorporating the "Alumon" Zincate immersion pretreatment with any one of the three tin plating baths (Procedure Nos. 1, 2 or 3 of Table II). Pretreatment No. 2, Oxalic Acid anodize, failed to produce aluminum surfaces which were receptive to electrodeposition, and no specimens were successfully plated by procedure nos. 4, 5, or 6 of Table II. The results of the visual inspection of the tin plated specimens prepared by procedures 1, 2 and 3 are given in Tables VI A (2024-T6) and VI B (7075-T6).

B. Evaluation of Tin Plated Specimens:

1. Adhesion Tests: Adherent tin platings were produced on both aluminum alloys by procedure nos. 1, 2 and 3. The results of tape stripping, bend, and thermal cycling tests are given in Table VII.

2. Salt Spray Tests: Exposure of tin plated specimens to 200 hours in salt spray environment showed excessive corrosion of the specimens prepared by plating procedure nos. 1 and 3 (Fluoborate and Stannous Sulfate baths, respectively), while procedure no. 2 (Sodium Stannate bath) produced plates which offered an acceptable degree of corrosion resistance. The results of these tests are given in Table VIII and are shown in Figures 1 and 2.

3. Galvanic Corrosion Tests: Couples of tin plated aluminum-magnesium-thorium alloys exhibited no evidence of corrosion after 100 hours immersion in a three-phase JP-4 - 3% salt water system. The results of these tests are given in Table IX and a typical specimen (after exposure) is shown in Figure 3.

DISCUSSION:

The preliminary attempts to electroplate aluminum alloys with tin resulted in the deposition of porous platings. Close investigation of the specimens during plating revealed an etching reaction between the plating baths and the aluminum base material. This reaction was due to the porosity of the extremely thin standard copper strike (approximately 0.00001"), and further copper electroplating was employed to produce a protective, non-porous coating. After receiving copper plates of 0.0001" thickness, the specimens were tin plated very successfully.

Pretreatment method no. 2, Oxalic Acid anodize, failed to produce a plateable surface on the aluminum alloy coupons. Several variations of the requested pretreatment procedure were evaluated during this test without success. This substantiates results obtained earlier concerning the unsuccessful use of Oxalic Acid anodize pretreatment prior to chromium plating of aluminum alloys. As a result, procedure nos. 4, 5 and 6 (all employing Oxalic Acid anodize pretreatment) were found unsatisfactory.

A good comparison of the porosity of the tin plates produced by the three plating baths evaluated in this test is given in Table VIII. Salt spray exposure revealed that the plates produced on both 2024-T6 and 7075-T6 aluminum alloys from the Sodium Stannate tin bath were less porous than plates produced by the other two baths. The test also shows that the Stannous Fluoborate platings were less porous than the Stannous Sulfate platings. Figures 1 and 2 show specimens tin plated from the various baths after 200 hours salt spray exposure.

The galvanic corrosion specimens (tin plated aluminum coupled to mag-thorium as stated in Table IV) exhibited no evidence of corrosion after 100 hours exposure to a three-phase JP-4 - 3% salt water environment. Electrical continuity between aluminum and mag-thorium was definitely established prior to immersion of the couples and was rechecked after specimens had undergone 50 hours exposure. Several previous experiments (FTDM-1840, FTDM-1925 still unpublished, and T.R.F-6681 still in testing) reported severe corrosion of tin plated aluminum-magnesium-thorium couples while in three-phase immersion tests. The referenced tests differed from this test in the following respects: (1) Specimens used in the referenced tests were subjected to 21 days of overall testing, comprised of 3 cycles of repeated baking periods of 6 hours duration at 260°F, cooling to room temperature, exposure to 100°F-100% relative humidity for 16 hours, drying, and 96 hours immersion in a 3-phase JP-4 - 3% salt water system. The specimens used in this test were subjected only to 100 hours of 3-phase JP-4 - 3% salt water immersion. (2) The referenced tests employed specimens of a different configuration, using tin plated angles coupled to mag-thorium through 4 rivets, whereas this procedure used flat tin plated coupons coupled to the mag-thorium by a single rivet. In both configurations the ratio of aluminum to magnesium (sacrificial anode) remained the same.

The full 21-day cycling procedure evidently had a detrimental effect on the organic coatings applied to the specimens used in the referenced tests. This allowed the corrosive media of the 3-phase system to attack the couples.

CONCLUSIONS:

The physical and chemical properties of tin electrodeposited on 2024-T6 and 7075-T6 aluminum alloys were investigated. The results of these investigations lead to the following conclusions:

1. Attractive, adherent tin platings can be produced on 2024-T6 and 7075-T6 aluminum alloys by utilizing the "Alumon" zincate immersion pretreatment followed by any one of the three tin plating baths evaluated.

2. The Oxalic Acid anodize pretreatment does not produce aluminum surfaces which are receptive to the electrodeposition of tin from any of the baths evaluated.

3. The Sodium Stannate bath produced tin platings on 2024-T6 and 7075-T6 aluminum alloys which pass 200-hours salt spray exposure (with more than one pit per square inch surface area being basis for failure). These platings exhibit less porosity than platings produced from the Stannous Fluoborate bath, which in turn produces platings of less porosity than the Stannous Sulfate bath. Neither the Fluobrate nor Sulfate tin platings passed 200-hours salt spray exposure.

4. Both tin plated aluminum alloys coupled to HK-31 magnesium-thorium alloy (per Table IV) exhibit no corrosion after exposure to 100 hours immersion in a three-phase JP-4 - 3% salt water environment.

TABLE I

MATERIALS AND EQUIPMENT

A. MATERIALS

ITEM	QUANTITY	USE	SOURCE
2024-T6 Aluminum Alloy (QQ-A-355b)	72 Coupons 0.040"x1"x5"	Plating Specimens	Reynolds Metals Co. Louisville, Ky.
7075-T6 Aluminum Alloy (QQ-A-283)	72 Coupons 0.040"x1"x5"	Plating Specimens	Reynolds Metals Co. Louisville, Ky.
HK-31 Magnesium Thorium Alloy (FMS-0046)*	24 Coupons 0.064"x3"x5"	Component for Galvanic Couple Specimens	Dow Chemical Co. Midland, Mich.
AN426-B5-5 Rivets	24	Joining Galvanic Couple Pieces	Convair Stock
No. 400 "Wet or Dry" Sandpaper (115-074001)	As Needed	Removal of Protrusions	Convair Stock
Epoxy Primer CXF-0001 (FMS-0071)	As Needed	Organic Coating For Galvanic Corrosion Specimens	General Paint Co. Tulsa, Okla.
Epoxy Paint CXF-0002 (FMS-0072)	As Needed	Organic Coating For Galvanic Corrosion Specimens	General Paint Co. Tulsa, Okla.
Tank Sealants** EC776 and 1610 (FMS-0008B)	As Needed	Applied on Rivets and Faying Surfaces	Minn. Mining & Mfg. Co., Minneapolis, Minn.
Dow Treatment Solution No. 17 (FPS-0045)	As Needed	Anodize Mag-Thorium Pads	Prepared in Chem. Lab.
JP-4 Fuel (MIL-F-5624C)	As Needed	3-Phase Immersion Tests	Convair Stock
Chemicals for Pre-treatment and Plating Baths	See Tables II and III	Application of Tin Plating	Chem. Lab. Stock
Standard Laboratory Chemicals	As Needed	As Needed	Chem. Lab. Stock

*FMS-0046 composition is equivalent to AMS 4384.
**EC 776 is a MIL-S-4383B top coat sealant.
EC 1610 is an integral fuel tank sealant.

TABLE I (Continued)

B. EQUIPMENT

ITEM	USE	SOURCE
Electroplating Apparatus	Plating of Specimens	Convair Built Lab. Equipment
Oven (R.T. to 400°F)	Thermal Cycling	Blue "M" Electric Co. Blue Island, Ill.
Oven (R.T. to 260°F)	Paint Curing	Convair Built Lab. Equipment
Aluminum Block Heaters (3)	3-Phase Immersion Tests	Convair Built Lab. Equipment
Salt Spray Chamber	Corrosion Environment	Industrial Filter and Pump Mfg. Co., Chicago, Ill.
Standard Laboratory Equipment	As Needed	Chem. Lab. Stock

TABLE II

PRETREATMENT AND PLATING PROCEDURES

The electroplating procedures evaluated during this test constitute a combination of two pretreatment and three plating systems. These combinations are given below:

I. PLATING PROCEDURES

Plating Procedure	Pretreatment System	Plating System
No. 1	No. 1, "Alumon" Zincate	A. - Fluoborate Tin Bath
No. 2	No. 1, "Alumon" Zincate	B. - Sodium Stannate Tin Bath
No. 3	No. 1, "Alumon" Zincate	C. - Stannous Sulfate Tin Bath
No. 4	No. 2, Oxalic Acid Anodize	A. - Fluoborate Tin Bath
No. 5	No. 2, Oxalic Acid Anodize	B. - Sodium Stannate Tin Bath
No. 6	No. 2, Oxalic Acid Anodize	C. - Stannous Sulfate Tin Bath

II. PRETREATMENT SYSTEMS AND PROCEDURES

A. Pretreatment System No. 1 ("Alumon" Zincate Immersion)

1. Methyl Ethyl Ketone Wipe
2. Trichloroethylene Vapor Degrease for 5 Minutes
3. Treat in 50% (Vol.) Nitric Acid for 3 Minutes at 180°F
4. Tap Water Rinse at Room Temperature (R.T.)
5. Alkaline Clean in 20 oz. Sodium Hydroxide/Gal. at R.T. for Minimum of 30 Seconds or until
   a. 2024-T6 Aluminum is reacting strongly and uniformly
   b. 7075-T6 Aluminum is uniformly sooty
6. Tap Water Rinse at R.T.
7. R.T. Dip in 50% (Vol.) Nitric Acid
8. Tap Water Rinse at R.T.
9. "Alumon" Zincate Immersion under following conditions:
   a. Composition - 540 grams per liter
   b. Time - 0.5 to 1.0 minute
   c. Temperature - 70°F
10. Repeat Steps 6 thru 9
11. Double Tap Water Rinse at R.T.
12. Plate Immediately

TABLE II (Continued)

B. Pretreatment System No. 2 (Traver's Oxalic Acid Anodize)

1. through 8. same as Pretreatment System No. 1 above
9. Oxalic Acid Anodize at following conditions:

   a. Composition - 8% Oxalic Acid by weight
   b. Temperature - 30°C
   c. Current Density - 10-15 amps/ft.^{2} (D.C.)
   d. Voltage - 56 Volts
   e. Time - 10-30 Minutes

10. Tap Water Rinse at R.T.
11. Sodium Cyanide Dip, 5 oz./gal., 3-5 minutes at R.T.
12. Tap Water Rinse at R.T.
13. Plate Immediately

III. PLATING SYSTEMS (See Table III for Bath Compositions and Operating Conditions)

A. Plating System No. A (Stannous Fluoborate Acidic Bath)

1. Copper Strike - 0.00001" (Estimated)
2. Copper Plate - 0.0001"
3. Tin Plate - 0.0005" - 0.00075"

B. Plating System No. B (Sodium Stannate Alkaline Bath)

1. Through 3. Same as III A above except Tin Plate from Sodium Stannate Bath

C. Plating System No. C (Stannous Sulfate Acidic Bath)

1. Through 3. Same as III A above except Tin Plate from Stannous Sulfate Bath

TABLE III

PLATING BATH COMPOSITIONS AND OPERATING CONDITIONS

I. COPPER STRIKE BATH

Composition:

Copper Cyanide	-	22.5 gms./liter
Sodium Cyanide	-	34.0 " "
Free Sodium Cyanide	-	9.0 - 15.0 gms./liter

Bath Temperature: 75 - 80°F

Anodes: Stainless Steel

Voltage: 6 Volts (D.C.)

Striking Time: 60 - 90 Seconds

II. COPPER PLATING BATH

Composition:

Copper Cyanide	-	26.0 gms./liter
Sodium Cyanide	-	35.0 " "
Sodium Carbonate	-	30.0 " "
Rochelle Salt	-	45.0 " "
Copper Metal	-	19.0 " "
Free Sodium Cyanide	-	5.6 " "

Bath Temperature: 75 - 80°F

Anodes: Copper Metal

Current Density: 30 amps/ft.^{2} (D.C.)

III. FLUOBORATE TIN PLATING BATH

Composition:

Stannous Fluoborate	-	200.0 gms./liter
Fluoboric Acid	-	50.0 " "
Boric Acid	-	25.0 " "
Beta Napthol	-	1.0 " "
Gelatin	-	6.0 " "
Tin (By Analysis)	-	80.0 " "

Bath Temperature: 75°F

Anodes: Tin Metal

Current Density: 40 amps/ft.^{2} (D.C.)

Agitation: None

Ratio (Anode to Cathode Area): (2:1)

TABLE III (Continued)

IV. SODIUM STANNATE TIN PLATING BATH

Composition:

Sodium Stannate	-	105.0 gms./liter
Sodium Hydroxide	-	9.0 " "
Sodium Acetate	-	15.0 " "
Tin (By Analysis)	-	40.0 " "

Bath Temperature: 145 - 155°F

Anodes: Tin Metal

Current Density: 15 amps/ft.^{2} (D.C.)

Agitation: None

Ratio (Anode-to-Cathode Area): (1:1)

NOTE: Care must be taken to maintain anode polarization film.

V. STANNOUS SULFATE TIN PLATING BATH

Composition:

Stannous Sulfate	-	56.0 gms./liter
Sulfuric Acid	-	98.0 " "
Cresol Sulfonic Acid	-	98.0 " "
Beta Napthol	-	1.0 " "
Gelatin	-	2.1 " "
Tin (By Analysis)	-	30.0 " "

Bath Temperature: 75 - 80°F

Anodes: Tin Metal

Current Density: 35 amps/ft.^{2} (D.C.)

Agitation: 10 ft./min. (Solution flow rate)

Ratio (Anode-to-Cathode Area): (1:1)

TABLE IV

PREPARATION OF TIN PLATED ALUMINUM - MAG-THORIUM GALVANIC CORROSION SPECIMENS

A. Twenty-four tin plated aluminum specimens were coupled to HK-31 magnesium to form galvanic corrosion specimens. Twelve of these specimens were of 7075-T6 and twelve of 2024-T6 aluminum alloys. Four specimens of each alloy were electroplated by each of the first three plating procedures given in Table II.

B. Dow "17" Treatment for HK-31 Mag-Thorium Pads

1. Methyl Ethyl Ketone Wipe
2. Trichloroethylene Vapor Degrease
3. Immerse for 8 minutes in 85% Phosphoric Acid at room temperature to remove mill scale
4. Tap Water Rinse at R.T.
5. Treat in the following solution as indicated:

a.	Ammonium bifluoride	-	32 oz/gal
b.	Sodium chromate	-	13.3 oz/gal
c.	Phosphoric acid	-	11.5 fl. oz/gal
d.	Water	-	To one gal.
e.	Temperature	-	180°F
f.	Current Density	-	12 amps/ft.^{2} (A.C.)
g.	Final Voltage	-	72 volts (A.C.)

6. Tap Water Rinse at R.T.
7. Place in 260°F oven for 10 to 30 minutes

C. Apply organic coating to tin plated aluminum and HK-31 magnesium pad as follows:

1. Coat aluminum and magnesium components with General Paint Company's CXF-0001 Epoxy Primer to a thickness of 0.8 ±0.05 mils.
2. Air dry for 30 minutes at 77°F, then cure for 30 minutes at 260°F.
3. Remove foreign matter and protrusions with No. 400 wet or dry sandpaper.
4. Coat with Epoxy Enamel CXF-0002 (General Paint Company) to a thickness of 0.8 ±0.05 mils.
5. Air dry for 30 min. at 77°F then cure for 30 min. at 260°F.
6. Repeat Steps #3 and #4.

D. Apply Tank Sealant EC1610 (Minnesota Mining & Mfg. Co.) to interface between aluminum and magnesium components.

E. Apply Sealant EC-776 (Minnesota Mining & Mfg. Co.) along edges of magnesium pads.

F. Join components with one AN-426-B5-5 rivet.

G. Apply Tank Sealant EC-1610 (Minnesota Mining & Mfg. Co.) to head and tail of rivet.

TABLE IV (Continued)

H. Allow 5 hours air curing at room temperature plus 24 hours at 260°F.

I. Check specimens for electrical continuity between aluminum and magnesium components.

TABLE V

EVALUATION OF TIN PLATED SPECIMENS

1. Visual Inspection: All specimens were observed for smoothness, excessive edge build-up, pits, blisters, and burned areas before further evaluations were performed. Results of this inspection are given in Table VI.

2. Adhesion:

   A. Tape Stripping Test: Pressure sensitive tape 3M #250 was firmly applied to one specimen of each alloy and plating procedure. The tape was then rapidly removed by pulling in a direction perpendicular to the plated surface. The tape and specimen were examined for evidence of faulty or non-adherent plate. Any failure was considered as cause for rejection. Results of this test are given in Table VII.

   B. Bend Test: One specimen from each alloy and plating procedure was repeatedly bent through an angle of 180 degrees (on a diameter equal to twice the thickness of the specimen) until fracture of base metal occurred. Examination was then made for loss of plate adhesion within the bend area and along the interface between the plate and base material. Results of this test are given in Table VII.

   C. Thermal Cycling Test: Two specimens from each alloy and plating procedure received thermal shock tests. This was performed by subjecting the specimens to 425°F temperature for 3 minutes and then immediately immersing them in 70-80°F tap water for one minute. This cycle was repeated a total of three times. Specimens were inspected for discoloration, blistering, or peeling of plate. Results of this test are given in Table VII.

3. Corrosion Testing:

   A. Salt Spray Corrosion Test: This test was performed in accordance with Federal Test Method Standard No. 151, Method No. 811. Two specimens from each alloy and plating procedure were subjected to salt spray environment for 200 hours. Corrosion in excess of one pit per square inch of plated area was considered cause for failure. Results of this test are given in Table VIII and shown in Figures 1 and 2.

   B. JP-4 - 3% Salt Water Immersion Tests: Two galvanic corrosion specimens from each alloy and plating procedure were subjected to 100 hours immersion in a JP-4 - 3% salt water corrosion environment at a temperature of 140°F. This constitutes a portion of the complete revised WADC three phase test. Specimens were inspected and checked for electrical continuity after each 50 hour exposure. Results from this test are given in Table IX and shown in Figure 3.

TABLE VI-A

PRE-EXPOSURE VISUAL INSPECTION OF
TIN ELECTROPLATED 2024-T6 ALUMINUM SPECIMENS

PLATING METHOD	SPECIMEN NUMBER	CONDITION OF PLATED SPECIMENS					
		SURFACE ROUGHNESS	EDGE BUILD-UP	VISIBLE PITS	BLISTERS	BURNS	COLORATION
#1 (Fluoborate)	1	Fair	Slight	None	None	None	Fair
	2	"	"	"	"	"	"
	3	"	"	"	"	"	"
	4	Fair	"	"	"	"	"
	5	Good	"	"	"	"	"
	6	Fair	"	"	"	"	"
	7	"	"	"	"	"	"
	8	Poor	"	"	"	"	"
	9	Good	"	"	"	"	"
	10	Fair	"	"	"	"	" (Grey)
	11	Poor	"	"	"	"	"
	12	Good	Slight	None	None	None	Fair
#2 (Stannate)	1	Good	Slight	None	None	None	Fair
	2	"	"	"	"	"	"
	3	"	"	"	"	"	Good
	4	"	"	"	"	"	"
	5	"	"	"	"	"	"
	6	"	"	"	"	"	"
	7	"	"	"	"	"	"
	8	"	"	"	"	"	"
	9	"	"	"	"	"	"
	10	"	"	"	"	"	"
	11	"	"	"	"	"	"
	12	Good	Slight	None	None	None	Fair
#3 (Sulfate)	1	Fair	Slight	None	None	None	Fair
	2	"	"	"	"	"	"
	3	"	"	"	"	"	"
	4	Good	"	"	"	"	"
	5	Fair	"	"	"	"	"
	6	Poor	"	"	"	Moderate	"
	7	Fair	"	"	"	None	"
	8	Fair	"	"	"	"	"
	9	"	"	"	"	"	"
	10	Poor	"	"	"	"	"
	11	Fair	"	"	"	"	"
	12	Good	Slight	None	None	None	Fair

TABLE VI-B

PRE-EXPOSURE VISUAL INSPECTION OF
TIN ELECTROPLATED 7075-T6 ALUMINUM SPECIMENS

PLATING METHOD	SPECIMEN NUMBER	CONDITION OF PLATED SPECIMENS					
		SURFACE ROUGHNESS	EDGE BUILD-UP	VISIBLE PITS	BLISTERS	BURNS	COLORATION
#1	1	Fair	Slight	None	None	None	Fair
(Fluoborate)	2	Good	"	"	"	"	Good
	3	Fair	"	"	"	"	Fair
	4	"	"	"	"	"	"
	5	"	"	"	"	"	"
	6	"	"	"	"	"	"
	7	Good	"	"	"	"	Good
	8	Fair	"	"	"	"	Fair
	9	Good	"	"	"	"	"
	10	"	"	"	"	"	"
	11	"	"	"	"	"	"
	12	Fair	Slight	None	None	None	Fair
#2	1	Good	Slight	None	None	None	Good
(Stannate)	2	"	"	"	"	"	"
	3	"	"	"	"	"	"
	4	"	"	"	"	"	"
	5	"	"	"	"	"	"
	6	Fair	"	"	"	"	Fair
	7	Good	"	"	"	"	Good
	8	"	"	"	"	"	"
	9	"	"	"	"	"	Fair
	10	"	"	"	"	"	Good
	11	"	"	"	"	"	"
	12	Good	Slight	None	None	None	Good
#3	1	Fair	Slight	None	None	Moderate	Fair
(Sulfate)	2	"	"	"	"	None	"
	3	"	"	"	"	Moderate	"
	4	Good	"	"	"	None	"
	5	Poor	"	"	"	"	"
	6	Good	"	"	"	"	"
	7	"	"	"	"	"	"
	8	"	"	"	"	"	"
	9	"	"	"	"	"	"
	10	Fair	"	"	"	"	"
	11	"	"	"	"	"	"
	12	Fair	Slight	None	None	None	Fair

TABLE VII

RESULTS OF PHYSICAL TESTS ON TIN
ELECTROPLATED 2024-T6 AND 7075-T6 ALUMINUM ALLOYS

A. MECHANICAL ADHESION TESTS ON 2024-T6 ALUMINUM ALLOY SPECIMENS

PLATING METHOD	SPECIMEN NUMBER	TYPE OF ADHESION FAILURE			
		AFTER TAPE STRIPPING	DURING FLEXING	AT INTERFACE AFTER FAILURE	CONCLUSIONS
#1 (Fluoborate)	1	None	None	None	Pass
	2	None	None	None	Pass
#2 (Stannate)	1	None	None	None	Pass
	2	None	None	None	Pass
#3 (Sulfate)	1	None	None	None	Pass
	2	None	None	None	Pass

B. MECHANICAL ADHESION TESTS ON 7075-T6 ALUMINUM ALLOY SPECIMENS

PLATING METHOD	SPECIMEN NUMBER	TYPE OF ADHESION FAILURE			
		AFTER TAPE STRIPPING	DURING FLEXING	AT INTERFACE AFTER FAILURE	CONCLUSIONS
#1 (Fluoborate)	1	2 small areas	None	None	Pass
	2	None	None	None	Pass
#2 (Stannate)	1	None	None	None	Pass
	2	None	None	None	Pass
#3 (Sulfate)	1	None	None	None	Pass
	2	None	None	None	Pass

TABLE VII (Continued)

C. THERMAL CYCLING (425 to 75°F) ADHESION TESTS ON 2029-T6 ALUMINUM ALLOY SPECIMENS

PLATING METHOD	SPECIMEN NUMBER	TYPE OF PLATE FAILURE			
		PEELING OF PLATE	BLISTERING OF PLATE	DISCOLORATION OF PLATE	CONCLUSIONS
#1 (Fluoborate)	3	None	None	None	Pass
	4	None	None	None	Pass
#2 (Stannate)	3	None	None	None	Pass
	4	None	None	None	Pass
#3 (Sulfate)	3	None	None	None	Pass
	4	None	None	None	Pass

D. THERMAL CYCLING (425 to 75°F) ADHESION TESTS ON 7075-T6 ALUMINUM ALLOY SPECIMENS

PLATING METHOD	SPECIMEN NUMBER	TYPE OF PLATE FAILURE			
		PEELING OF PLATE	BLISTERING OF PLATE	DISCOLORATION OF PLATE	CONCLUSIONS
#1 (Fluoborate)	3	None	None	None	Pass
	4	None	None	None	Pass
#2 (Stannate)	3	None	None	None	Pass
	4	None	None	None	Pass
#3 (Sulfate)	3	None	None	None	Pass
	4	None	None	None	Pass

TABLE VIII

EFFECTS OF 200-HOURS SALT SPRAY EXPOSURE ON TIN PLATED 2024-T6 AND 7075-T6 ALUMINUM ALLOYS

A. TIN PLATED 2024-T6 ALUMINUM ALLOY

PLATING METHOD	SPECIMEN NUMBER	PITS PER SQUARE INCH SURFACE AFTER 50 HRS EXPOSURE	AFTER 120 HRS EXPOSURE	AFTER 200 HRS EXPOSURE	AVERAGE PITS/SQ." AFTER 200 HRS	CONCLUSIONS SPEC-IMEN	PROCEED-URE
#1 (Fluoborate)	5	2.6	2.6	2.6		Fail	
	6	0.6	0.8	0.8	1.65	Pass	Fail
	7	1.2	1.2	1.2		Fail	
	8	2.0	2.0	2.0		Fail	
#2 (Stannate)	5	0.2	0.2	0.8		Pass	
	6	1.2	1.2	1.4	0.8	Fail	Pass
	7	0.6	0.6	0.6		Pass	
	8	0.2	0.2	0.4		Pass	
#3	5	1.6	1.6	1.4*		Fail	
	6	5.0	5.0	5.2	2.9	Fail	Fail
	7	2.6	2.4*	2.2*		Fail	
	8	3.0	2.8*	2.8		Fail	

B. TIN PLATED 7075-T6 ALUMINUM ALLOY

PLATING METHOD	SPECIMEN NUMBER	PITS PER SQUARE INCH SURFACE AFTER 50 HRS EXPOSURE	AFTER 120 HRS EXPOSURE	AFTER 200 HRS EXPOSURE	AVERAGE PITS/SQ." AFTER 200 HRS	CONCLUSIONS SPEC-IMEN	PROCEED-URE
#1 (Fluoborate)	5	1.0	1.0	1.0		Pass	
	6	1.0	1.0	1.0	1.05	Pass	Fail
	7	0.8	0.8	1.0		Pass	
	8	1.2	1.2	1.2		Fail	
#2 (Stannate)	5	0.8	1.0	1.2		Fail	
	6	0.4	0.4	0.4	0.85	Pass	Pass
	7	0.4	0.4	0.4		Pass	
	8	1.2	1.4	1.4		Fail	
#3 (Sulfate)	5	3.8	4.0	4.4		Fail	
	6	2.6	2.6	3.2	3.7	Fail	Fail
	7	4.2	4.8	5.6		Fail	
	8	1.4	1.4	1.6		Fail	

* NOTE: Decrease in number of pits is caused by pits growing together.

TABLE IX

EFFECTS OF 100-HOURS EXPOSURE TO THREE-PHASE IMMERSION TESTING (3% SALT WATER - JP-4) ON TIN PLATED ALUMINUM - MAG THORIUM GALVANIC CORROSION SPECIMENS

A. TIN ELECTROPLATED 2024-T6 ALUMINUM ALLOY SPECIMENS

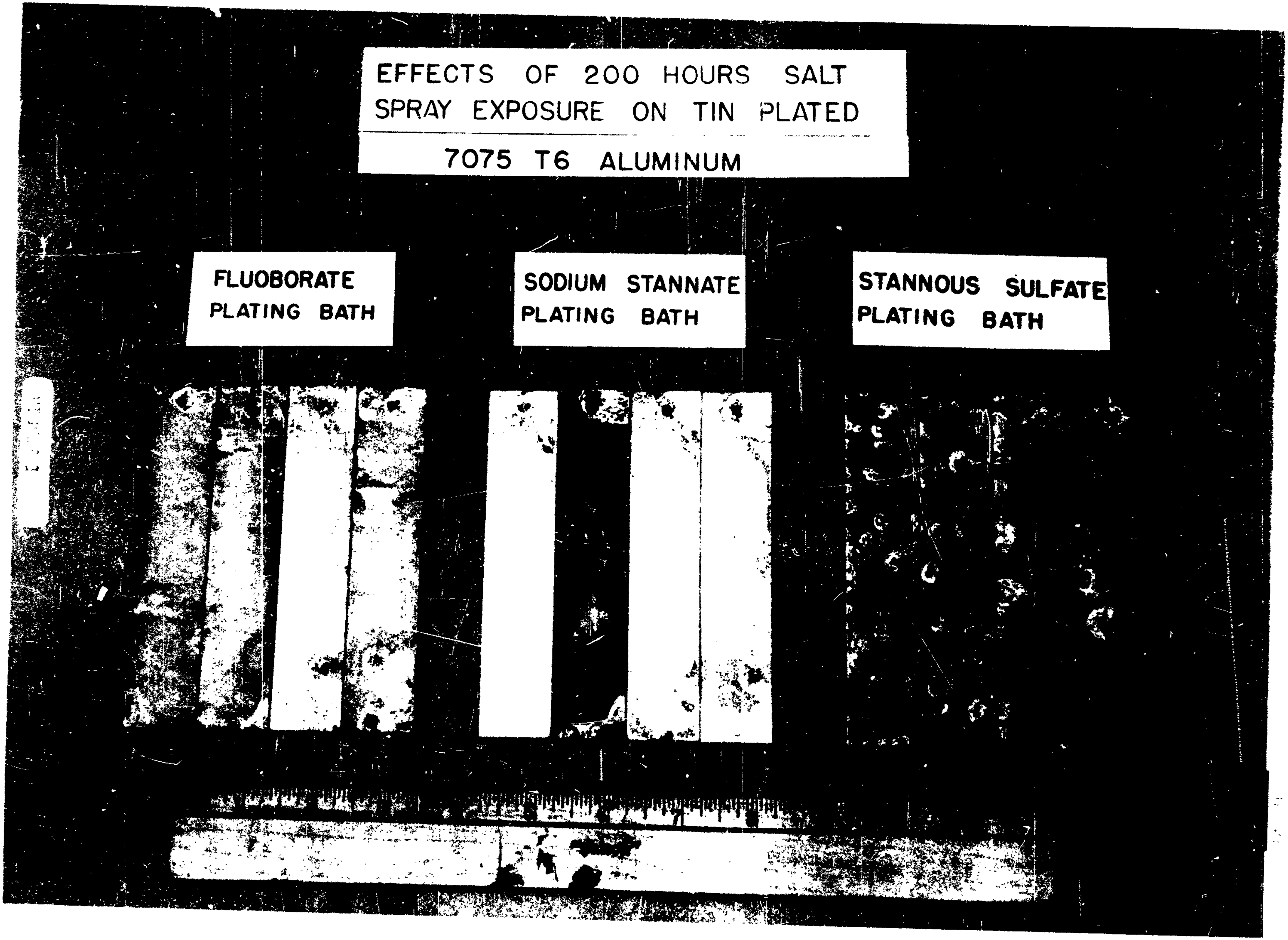
PLATING METHOD	SPECIMEN NUMBER	CONDITION OF SPECIMENS: PEELING OF PAINT	CONDITION OF SPECIMENS: CORROSION OF COMPONENTS	CONCLUSION
#1 (Fluoborate)	9	None	None	Pass
	10	None	None	Invalid*
	11	None	None	Invalid*
	12	None	None	Pass
#2 (Stannate)	9	None	None	Pass
	10	None	None	Pass
	11	None	None	Pass
	12	None	None	Pass
#3 (Sulfate)	9	None	None	Pass
	10	None	None	Pass
	11	None	None	Pass
	12	None	None	Pass

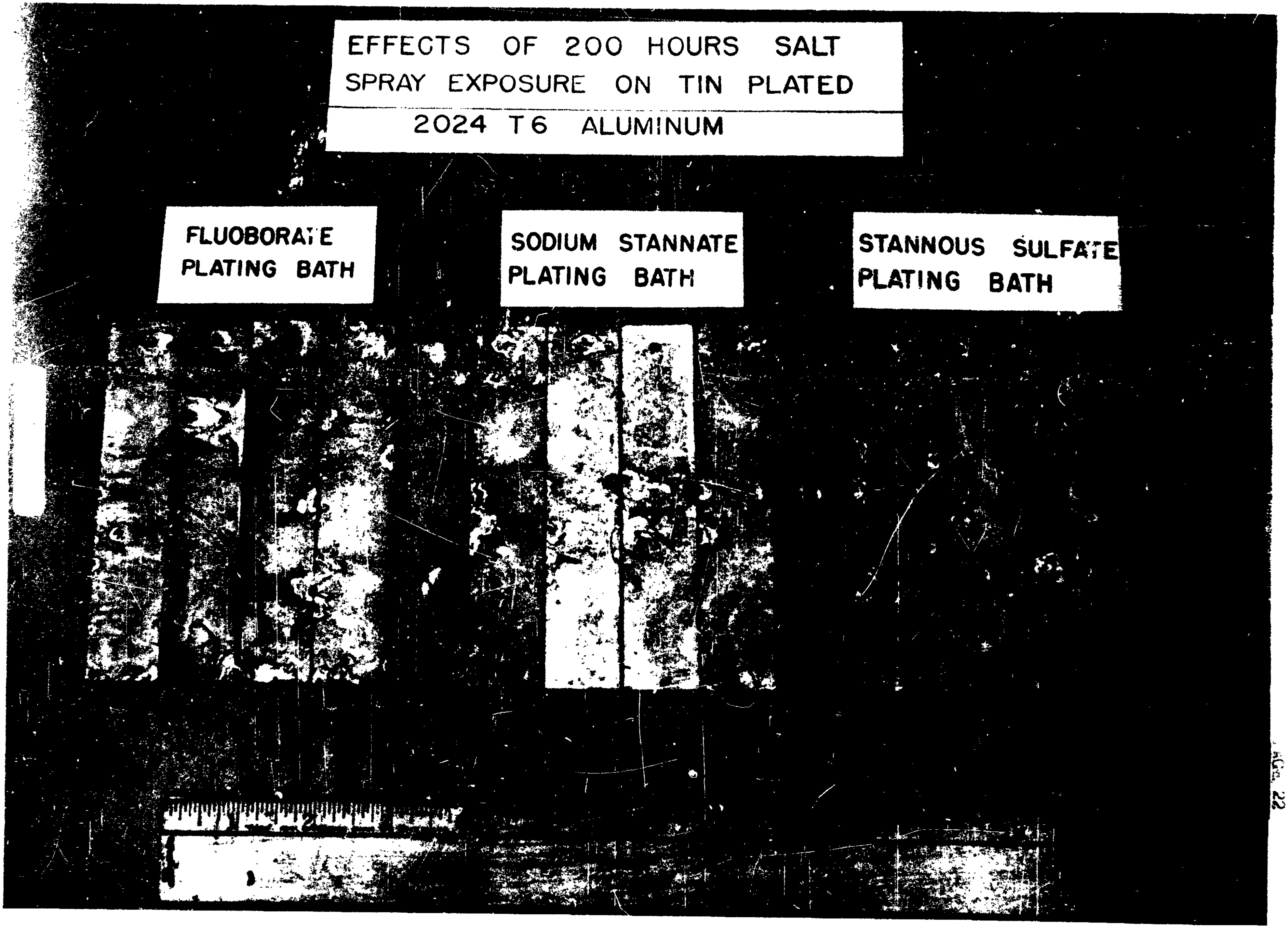
B. TIN ELECTROPLATED 7075-T6 ALUMINUM ALLOY SPECIMENS

PLATING METHOD	SPECIMEN NUMBER	CONDITION OF SPECIMENS: PEELING OF PAINT	CONDITION OF SPECIMENS: CORROSION OF COMPONENTS	CONCLUSION
#1 (Fluoborate)	9	None	None	Pass
	10	None	None	Pass
	11	Slight	None	Pass
	12	None	None	Pass
#2 (Stannate)	9	None	None	Invalid*
	10	None	None	Invalid*
	11	None	None	Pass
	12	None	None	Invalid*
#3 (Sulfate)	9	None	None	Pass
	10	None	None	Pass
	11	None	None	Pass
	12	None	None	Pass

*NOTE: These specimens were overheated due to failure of thermal switch during exposure period.

PHOTOGRAPH INDEX


EFFECTS OF 200 HOURS SALT
SPRAY EXPOSURE ON TIN PLATED
7075 T6 ALUMINUM
FLUOBORATE
PLATING BATH
SODIUM STANNATE
PLATING BATH
STANNOUS SULFATE
PLATING BATH


EFFECTS OF 200 HOURS SALT
SPRAY EXPOSURE ON TIN PLATED
2024 T6 ALUMINUM
FLUOBORATE
PLATING BATH
SODIUM STANNATE
PLATING BATH
STANNOUS SULFATE
PLATING BATH